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CHARACTERISTICS OF PRODUCTS GENERATED BY SELECTIVE SINTERING AND STEREOLITHOGRAPHY RAPID PROTOTYPING PROCESSES

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I. INTRODUCTION

The trend in the modern global economy towards free market policies has motivated companies to use rapid prototyping technologies to not only reduce product development cycle time but also to maintain their competitive edge.(1). A rapid prototyping technology is one which combines computer aided design with computer controlled tracking of a focussed high energy source(eg.lasers,heat) on modern ceramic powders, metallic powders,plastics or photosensitive liquid resins in order to produce prototypes or models. At present, except for the process of shape melting (2), most rapid prototyping processes generate products that are only dimensionally similar to those of the desired end product.

There is an urgent need, therefore,to enhance the understanding of the characteristics of these processes in order to realize their potential for production. Currently, the commercial market is dominated by four rapid prototyping processes, namely selective laser sintering,stereolithography, fused deposition modelling and laminated object manufacturing. This phase of the research has focussed on the selective laser sintering and stereolithography rapid prototyping processes. A theoretical model for these processes is under development. Different rapid prototyping sites supplied test specimens (based on ASTM 638-84,Type I) that have been measured and tested to provide a data base on surface finish, dimensional variation and ultimate tensile strength.

Further plans call for developing and verifying the theoretical models by carefully designed experiments. This will be a joint effort between NASA and other prototyping centers to generate a larger database, thus encouraging more widespread usage by product designers.

II. PROCESS CHARACTERISTICS

All rapid prototyping processes start with the development of a CAD model (usually a three dimensional solid model) of the finished part. This model is then "sliced" into different layers starting from the bottom of the part upwards. Each slice is then downloaded to the control computer for the actual creation of the part in the selected rapid prototyping machine.

A schematic view of a selective laser sintering machine is shown in Fig 1. The process is initiated by depositing a thin uniform layer of powder under carefully controlled temperature and atmosphere conditions (3). The levelling drum maintains the thickness of the layer between .003" and .010". The computer controlled laser beam rasters the top surface of

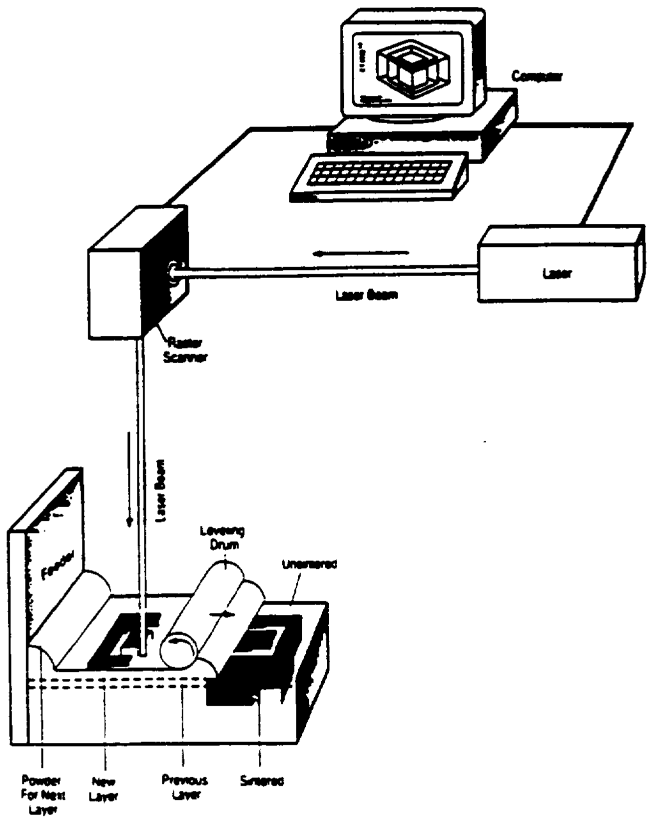

Figure 1. Schematic of Selective Laser Sintering Process.

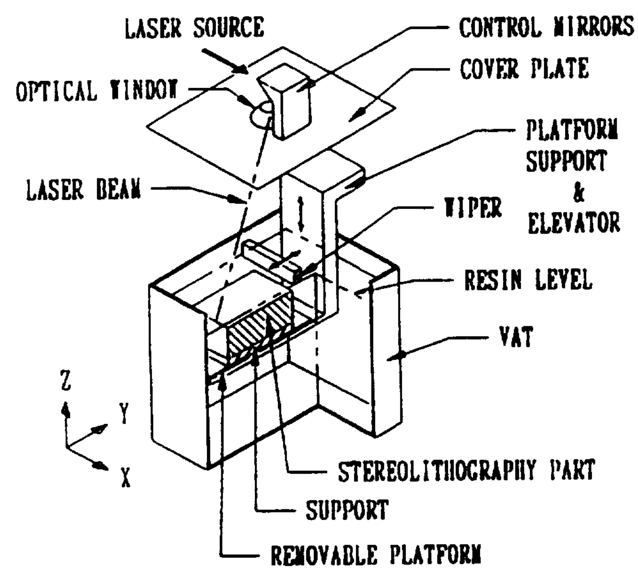

Figure 2 Setup of a StereoLithography Machine.

the powder bed according to the geometry of the "slice that is being processed. A typical diameter for the laser beam is 0.02" and its working output power ranges from 5 W to 50 W. This fuses the powder together at the interface of the beam. The scanning velocity of the laser beam on the surface of the powder ranges from 0.8-2.4 inches/s for metal and ceramic powders to 40 inches/s for polymers and waxes. At the end of the first layer, a second layer of loose powder is deposited and the process continues with the sintering material in the second layer binding to the previous layer. The process continues until the part is completed. Since the laser fuses only powder that it contacts, the finished part may be removed quite easily from the chamber.

A cross section of the stereolithography machine is shown in Fig 2. The process is initiated by raising the platform above the level of the resin by a predetermined amount. After a suitable waiting period, the laser traverses across this thin film to create what is known as a "supports" structure. This structure is created between the desired part and the platform to facilitate part removal without damaging it. The platform contacts the resin and polymerizes it thus creating a semi-rigid form of the desired geometry. The platform lowers below the resin layer for a recoating process and then raises again to a level that is one layer thickness below that of the

again to a level that is one layer thickness below that of the previous layer, and the laser is activated again to scan the new layer. This process continues until the support is completed. The product is created on this support structure in a similar fashion with the additional step in the process sequence of moving the wiper across the surface of the resin to maintain a uniform layer thickness of 0.005" to 0.010" after each recoating step. In addition, the scanning pattern may be changed to suit product geometry. After the product is completed, it is then gently removed from the platform ,the supports are carefully scraped away and the product is placed in a post cure chamber for the final curing stage where it attains its final properties.

III THEORETICAL BACKGROUND

The principles behind the SLS process (3) indicate that the lasing action melts the powder and a resulting binding mechanism is a combination of melting of the powder and viscous flow of the molten phase. Other contributing factors include powder particle size and shape,powder properties at different temperatures,laser power density, and chamber atmosphere control.

The SLA process is based on the principle that laser scanning initiates the release of free radicals in the photopolymeric resin. A chain reaction that results causes polymerization of the resin (4,5). Important parameters that also contribute to this process include hatch spacing, cure depths, wait time and post cure strategies.

IV EXPERIMENTAL SETUPS

Tensile test specimens (ASTM D638-84,Type 1) for the SLS machine were created by Rocketdyne Inc.(CA),using polycarbonate powder as the raw material. Parameters that were varied were laser power (low and high), build direction (face and edge) and use of sealant(no sealant and sealant). Surface finish, gage length dimensions and ultimate tensile strength were the obtained for each specimen.

Similar test specimens made by the SLA process were obtained from Pratt and Whitney (FL) and DEI (VA). Parameters that were varied were the build direction (edge, face and vertical) and layer thickness (0.005" and 0.010").Other parameters were maintained at their default values.

V. SUMMARY OF THE RESEARCH.

Since critical information on these two processes is proprietary the theoretical models require further development. Testing of the samples has allowed certain deductions to be made. For example, surfaces of the SLS process,parallel to the powder bed surface had a superior surface finish (65 - 520 microinches) than those produced

perpendicular to the powder bed surface (144 - 840 microinches). In addition sealed products had better finishes than unsealed products. Dimensional deviations were in the range of).003" to 0.007". Ultimate tensile strength ranged from 1904 to 5616 psi. A statistical model predicted that the product with the highest strength (5378 psi) could be built with low laser power, flat orientation and be sealed with an epoxy. This was comparable to ASTM D3935-87 for polycarbonate material (5800 psi).

Only the Pratt and Whitney stereolithography samples were statistically satisfactory and generated products with a surface finish range of 42 - 240 microinches. The ultimate tensile strength values ranged from 2263 to 3162 psi (std. dev. range was 94 to 330 psi). Since the standard deviations of tensile strength was large ,no deductions can be made about the contribution of the individual process parameters. Also, since the post processing involved clamping of the parts, surface finish measurements must be treated with caution.

VI.CONCLUSIONS.

Some quantitative measures have been established about the SLS and SLA rapid prototyping processes.Further development on the theoretical models is required in order to enhance the quality of predictions about these processes. The range of parameters in rapid prototyping processes and corresponding variety in materials add complexity to this endeavor. Despite these issues rapid prototyping offers a tangible trend towards reduction in product development times.

VII ACKNOWLEDGEMENTS

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